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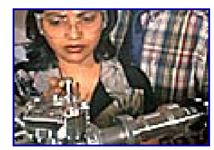

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Research Horizons

Gorillas in the Bits

Remote sensing technology boosts efforts to protect endangered mountain gorillas and rebuild Rwanda's economy.

By John Toon

For nearly 18 years until her death in 1985, naturalist Dian Fossey studied the lives of mountain gorillas living in the Virunga Mountain Range of northern Rwanda. Armed with a camera, binoculars and field journal, she and a community of local trackers documented intimate details of what the gorillas did, where they went, what they ate, and how they interacted with one another. Her work, popularized by the movie "Gorillas in the Mist," left a treasure trove of information about these highly endangered creatures.

Now, scientists continuing her work are gaining a powerful new set of research tools, thanks to a partnership between conservation organizations and universities on two separate continents. The partnership will put the technologies of remote sensing into the hands of field scientists working to protect the gorillas — while helping Rwanda rebuild its national university and recover from a devastating 1994 war and genocide.

photo by Nickolas Faust

A family of mountain gorillas relaxes in the lush vegation of the Virunga Mountain Range during a rain storm. (300-dpi JPEG version - 553k)

It may also serve as a demonstration of how advanced technologies can boost the struggle to protect other endangered species.

"Our first goal is to use modern-day technology to bring new clout to field conservation, ecosystem management and endangered species protection," explains Clare Richardson, president of the Dian Fossey Gorilla Fund International, an organization based in Atlanta. "Because we are a field conservation organization, it is imperative that we aggressively pursue more efficient ways to collect data, then have experts available to analyze that data, especially as it applies to habitat."

Assessing Gorilla Habitat

Habitat loss poses the single greatest threat to the mountain gorillas, Richardson says. The most densely populated nation in Africa, Rwanda today struggles with the task of resettling more than a million people in the aftermath of war. The need for more crop land, as well as timber for homes and cooking, threatens the protected reserves and introduces human disease into fragile gorilla habitat.

The first applications of the new technology, therefore, will be to assess existing gorilla habitat, explains Nickolas Faust, principal research scientist at the Georgia Tech Research Institute. Georgia Tech researchers will work with Dr. H. Dieter Steklis, chief scientist for the Dian Fossey Gorilla Fund International. They will combine geographic information system data from satellites with hyperspectral data gathered by a special aerial camera and demographic information recorded on the ground. That information includes the Fossey Fund's long-term database designed by Dian Fossey more than 30 years ago. This data will give researchers and Rwandan authorities a measure of how many gorillas the area can support, and establish a baseline for documenting future habitat loss.

"The carrying capacity of the area can be assessed by examining the quantity of preferred gorilla food," Steklis explains. "Based on that, we can determine how many gorillas the habitat can sustain. This would provide the park authorities with information that would help them manage the national park."

The technology may also help scientists understand complex environmental interactions that affect the gorillas. For instance, the gorillas seem to prefer certain areas of the forest, yet carefully avoid others. Scientists do not know why, but a more detailed understanding of the terrain, vegetation, water supply and other factors may provide clues.

photo by Gary Meek

Slightly more than 600 mountain

gorillas survive in Central East Africa, ranging across national parks controlled by three different nations: Rwanda, the Democratic Republic of Congo and Uganda. Security concerns in the border region over the last few years curtailed regular patrols of the gorilla habitat. In spite of this, the gorillas fared well, and the Karisoke trackers and scientists are now back in the Virungas with armed escorts.

Georgia Tech's involvement with the University of Rwanda included training two of its faculty and staff in GIS and remote sensing techniques. Paul Beatty, center, of the Georgia Tech Center for Geographic Information Systems discusses an image with Dr. Safari Bonfils, left, dean of engineering at the National University, and Ntihemuka Joel, a computer science technician there. (300-dpi JPEG version - 721k)

These indomitable trackers will soon receive additional training to make use of new technology. Working with researchers, they will break new ground in combining geographic information system (GIS) data with global positioning system (GPS) technology and wireless communications. Ultimately, wireless communications systems tied into the Internet will allow quick transfer of data from field scientists to biologists anywhere in the world.

"The idea of tying GIS, GPS and communications together is a fairly new concept that we hope to explore through this collaboration," Faust explains. "We will be bringing in technology that hasn't traditionally been used in field conservation."

The Fossey Fund's geographic information system and remote sensing program, begun in 1992, got a boost recently from an Idaho company, Earth Search Sciences Inc. (ESSI). As part of a National Geographic television project last year, ESSI gathered hyperspectral data — high-resolution images recorded simultaneously in multiple wavelengths. Turned over to Fossey Fund scientists and the Rwandan government, this information provides rich new detail about vegetation in the area, even allowing scientists to distinguish individual plant species.

Using GIS and other data, Georgia Tech also created a virtual Virungan environment on its Atlanta campus, using a three-screen projector system that allows visitors to immerse themselves in a three-dimensional simulation. By allowing a group of people to share the experience of moving through the ecosystem and examining its components, the Georgia Tech-developed system — known as the Non-Expensive Automatic Virtual Environment (NAVE) — offers a powerful tool for visualizing the potential impacts of change, Faust adds.

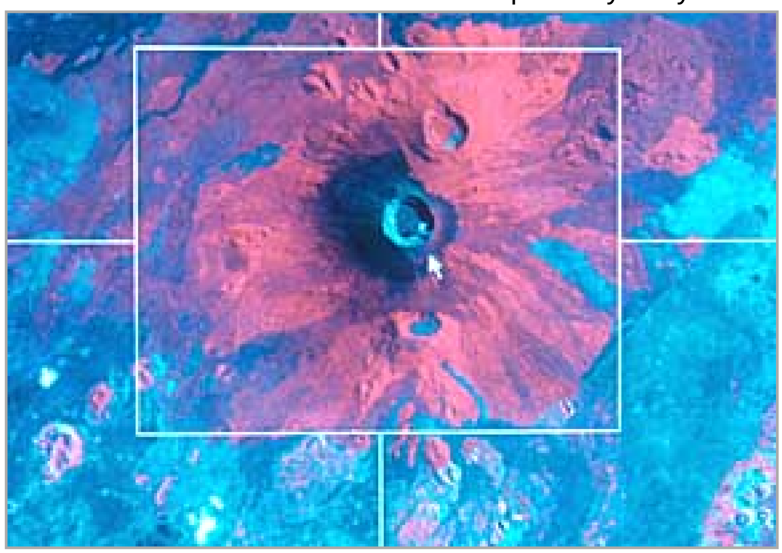
The multi-screen, multi-user stereoscopic system was designed to extend applications for virtual environments by dramatically reducing system cost. Developed by Dr. Larry Hodges, Dr. William Ribarsky and others in Georgia Tech's College of Computing, it relies on personal computers rather than costly workstations for rendering scenery.

Help from NASA's Data Resources

The partnership may also get help from the National Aeronautics and Space Administration (NASA), whose Digital Earth initiative seeks to make the agency's vast data resources, powerful imaging tools and 25 years of expertise available to field scientists. Dr. Timothy W. Foresman, national executive manager for the initiative based at NASA's Office of Earth Science in Washington, views the collaboration between Georgia Tech, the Dian Fossey Gorilla Fund International and the National University of Rwanda as a valuable demonstration project.

"We would like to utilize NASA resources to provide satellite imagery of the research area as a contribution to the project so we can better understand how GPS, remote sensing, GIS and environmental modeling are being used to make decisions in Rwanda," Foresman explains. "We will learn what really works in the field so we can begin to take these global resources and make them relevant to the people who really need them. This is not an ivory tower exercise."

photo by Gary Meek



Geographic Information System (GIS) data is being used to study land use in the fragile habitat that is home to the mountain gorillas. This image shows an inactive volcano that is part of the Virunga Mountain Range. (300-dpi JPEG version - 614k)

Like Faust, he wants to explore how different technologies can work together — especially now that data can so easily be provided across the global Internet. That could lead to development of a true global clearinghouse for digital data applicable to conservation, planning, resource management and other purposes. By using appropriate low-cost technologies and providing data, tools and consultation at no cost, Digital Earth will make these resources more widely available.

"Digital Earth is becoming a national and international framework for understanding how all these technologies come together, using the world's infrastructure to better understand human involvement with the earth," Foresman says. "All of these things cross borders because you can't do them in isolation.

Foresman says the next step in the NASA collaboration is to define the specific resources the space agency can apply to this project.

Interest Goes Beyond Gorillas

Though the Dian Fossey Gorilla Fund International focuses on conservation of the gorillas, the well-being of the animals cannot be separated from the well-being of the country in which they live. For that reason, the partnership has taken on broader goals.

"We would also like to take certain elements of these technology applications to the countries in which we work so that we are building scientific and technical infrastructure there," Richardson says. "We want to provide the training and equipment for local universities to learn to collaborate internationally. Ultimately, we want to have centers for GIS and remote sensing dotted all around the globe."

To further that goal, Faust and collaborators at Georgia Tech's Center for Geographic Information Systems — including director Steven French, Paul Beatty and Subramahyam Muthukuman — spent five weeks in February and March teaching two officials from the National University of Rwanda about GIS and remote sensing. Back at their university, the Rwandans will pass on their knowledge to additional faculty and students, using GIS workstations provided by Georgia Tech through the Georgia Research Alliance. Web-based course work designed by the Georgia Tech GIS Center will make such learning possible.

"We will set up the first center for GIS and remote sensing at the university, and our goal will be to train others in this new technology," says Dr. Safari Bonfils, dean of science and engineering at the National University of Rwanda. "The students will use this technology for applications in agriculture, social science and the sciences. This will be very helpful for our country, especially for planners in the government ministries."

A physicist by training, Bonfils sees long-term benefits to the university. "Our departments will use this technology to improve their research and teaching. This will bring current technology to our work."

The university plans to model its GIS center after Georgia Tech's, which serves as a statewide clearinghouse for remote sensing data. Centralizing GIS data and interpretation expertise at the national university will give Rwanda the most benefit from the equipment and investment, Faust notes.

photo by Gary Meek

Partners from Georgia Tech and the Dian Fossey Gorilla Fund International view Rwandan terrain on Georgia Tech's three-screen visualization system. The system allows viewers to immerse themselves in the scenery, facilitating discussion of land-use issues. (300-dpi JPEG version - k)

Beyond providing information useful for managing the gorilla habitat and planning for the country's needs, GIS and remote sensing technology could also help the government explore for minerals — and even update the nation's maps.

"With a minimal investment, we think we can do a lot of good for the government of Rwanda, as well as meet the needs for technology in conservation," Faust adds. "We will provide software and systems that will allow them to establish their own capability and provide services to the government."

Repairing the nation's infrastructure and encouraging good land-use planning is important to the gorillas' long-term survival. Before the 1994 genocide, income from ecotourism was important to Rwanda's economy, its second-largest source of outside revenue. If that tourism can be restored, the country will be better able to afford investments in protecting the gorillas.

"The relationship with Georgia Tech will help Rwanda enhance its capability to bring in new investment and develop its resources," Faust says. "The historical focus of the Fossey Fund is on conservation, but the longer-term goal is human and economic development for the entire region of Africa."

The Georgia Tech involvement, made possible by equipment funds from the Georgia Research Alliance, joins with similar efforts being made by other universities. One such project, led by the University of Maryland, will provide distance learning opportunities and help develop communications infrastructure in the country.

Applying the Lessons Learned

The issues faced by mountain gorillas in Rwanda parallel those of other endangered species elsewhere in the world, such as pandas in China and elephants in Zaire.

"Endangered species around the world are endangered because of threats to their habitat," Richardson notes. "The elements are the same for many endangered species. The habitat and vegetation will be different, but the elements of the model remain the same."

To expand the collaboration, the Fossey Fund, Georgia Tech, Clark Atlanta University, the Georgia Research Alliance and Zoo Atlanta expect to form a new Institute for Conservation, Research and Technology. This organization will provide information to other field scientists, and make technology available to other governments.

"If we can become an international clearinghouse for this data through expanded partnerships with the private, public and government sectors, then field scientists will be able to contact the Institute to obtain the remote sensing and spatial analysis information they need," Steklis explains. "This would allow field scientists to obtain the information they need at a minimal cost, and have the expertise available to interpret it."

The Georgia Research Alliance (GRA), a public-private organization that makes strategic economic development investments in Georgia's research universities, views the mountain gorilla project as a way to further Georgia Tech's application of sustainable technology to conservation.

"Our vision for this project is to help position Georgia Tech researchers as world leaders in the use of geographic information systems and other spatial analysis technologies for conservation," says GRA President C. Michael Cassidy. "When coupled with the field experience and expertise of our partners — the Dian Fossey Gorilla Fund International and Zoo Atlanta — this initiative will become a model for other conservation projects."

The equipment provided by the GRA played a crucial role in securing other investments, a role it has played often in Georgia. Says Richardson: "It was truly the catalyst for getting this program off the ground. We were able to leverage this commitment to involve others."

Zoo Atlanta Offers Learning Environment

Zoo Atlanta's international reputation for conservation and education will play a key role in sharing what the new Institute learns.

"The zoo is the major vehicle for public education," Richardson says. "Zoo Atlanta is not only a field research and conservation organization, but it also offers a wonderful education program that reaches a broad population that needs to hear the message of conservation."

Plans call for GIS and spatial analysis technology to be part of Zoo Atlanta's new Willie B. Conservation Center. There, through immersion environments like those at Georgia

Tech, visitors will be able to experience what researchers see in the Virunga Mountains.

A Unique Opportunity for Georgia Tech

Beyond the research and potential collaborations, the partnership offers Georgia Tech researchers and students a unique opportunity, and it furthers the institution's goal of applying its technology to environmental concerns worldwide.

"This is a major step for Georgia Tech to become more involved with international environmental applications," says Dr. Charles Liotta, Georgia Tech's vice-provost for research and dean of graduate studies. "This fits in well with the Georgia Tech's 'green engineering' initiative, and is a perfect test case with high visibility."

The project also offers broad-based potential applications for Georgia Tech's expertise in computing, planning, and environmental and civil engineering, he notes. In addition, it will make the most of the institution's existing collaborations and close ties to Zoo Atlanta.

Georgia Tech and the Dian Fossey Gorilla Fund International will pursue funding for the new Institute from national, local and international funding agencies, the private sector and foundations, Liotta says.

For Georgia Tech students, the gorilla project offers an opportunity to study in a laboratory unlike any other. Adds Faust: "This is an experimental laboratory in the real world. The applications for this are really boundless."

> **For more information,** contact Nickolas Faust, Electro-Optics Environment & Materials Laboratory, Georgia Tech Research Institute, Atlanta, GA 30332-0841. (Telephone: 404-894-0021) (E-mail: nick.faust@gtri.gatech.edu).
>
> **For information on NASA's program,** you may visit www.digitalearth.gov.

Research Horizons

Perspective

Georgia Tech research will help shape the 21st century's megatrends.

By Jane M. Sanders

The Georgia Institute of Technology was founded in 1888 upon the idea that education and research would invigorate the region's economy. Through the years, that idea has not only become a reality, it has exceeded expectations.

"Today, we have taken that idea to a new level by serving as a source of innovation and economic development not only for Georgia, but also for the nation," says President Wayne Clough.

Evidence arrived recently of success in Tech's service mission. A Southern Technology Council national survey ranked the institution as the number one academic player in economic development and university/industry technology transfer.

Georgia's leaders also view Tech as a catalyst for economic development. For example, Tech is playing a vital role in the Yamacraw Mission, a major statewide initiative to position Georgia as a world leader in high-technology industries. Over the next five to seven years, Yamacraw is expected to create several thousand new jobs in the lucrative fields of software engineering and electronic design. Many of those jobs will be filled by computer scientists and engineers trained at Tech.

Meanwhile, the Advanced Technology Development Center (ATDC), launched in 1980 and based at Georgia Tech, continues to incubate early-stage technology companies. In 1999, ATDC member companies attracted $130 million in investments from mergers, acquisitions, venture capital and other sources.

Also, engineers at the Georgia Tech Economic Development Institute counsel existing Georgia companies on productivity enhancement, quality control, cost reduction and new technology implementation.

Still at the heart of all this activity is "the basic philosophical principle that research is the precursor to discovery, and university research is the intellectual driver for the economic growth of this country," says Dr. Charles Liotta, vice provost for research.

It cannot go without noting that research volume at Georgia Tech reached its fifth consecutive all-time high of $280 million in fiscal year 1999 expenditures.

As you read this and all issues of Research Horizons magazine, we hope you make these connections between education, research and economic development. In this issue, they are evident in the stories of Digital Furnace, RF Solutions and even our special section on materials science and engineering research.

Research Horizons

RELATED MATERIALS STORIES

Biomaterials	Environmentally Benign Materials & Processes
Structural Materials	Materials Chemistry and Physics
Materials Processing	Microelectronic Materials

A Material World

Materials science and engineering research enables technologies that are improving life.

By Jane M. Sanders

It's 2015. Here's a day in the life of Tom. At 6 a.m., he heads for the Los Angeles airport in his lightweight, yet crashworthy, and aerodynamically optimized cast aluminum sports car. The vehicle is powered by a hydrogen-oxygen fuel cell, thus eliminating emissions into L.A.'s troubled, but improving, air. Tom crosses an old highway bridge that has been repaired just the day before with strips of carbon fiber-reinforced polymeric material.

At the airport, he boards a 300-passenger supersonic jet that will take him to Japan for a business lunch and return him to L.A. that afternoon. From the airplane, he uses a post-silicon era telecommunications system to send and receive voice and e-mail messages with his clients on the ground. Meanwhile, Tom, a diabetic, painlessly applies a microneedle patch to his arm. The patch contains a computer microchip that controls a miniature pump to deliver insulin to Tom as he needs it.

photo by Gary Meek

Mechanical and biomedical engineer Dr. Robert Guldberg and his research team are developing three-dimensional, implantable constructs to enhance the repair and regeneration of bone within an organism. One approach attempts to mimic the natural process of bone repair by implanting cartilage constructs created in an incubator into bone defects. (300-dpi JPEG version - 198k)

Back in L.A. that afternoon, Tom heads to his mountain climbing class where he practices scaling a wall using a specially tailored rope designed to dissipate the energy of a climber's fall and prevent the rope from completely failing in an accident. Tom ends the day resting in his climate-controlled home powered by his utility company's highly efficient, low-emission gas turbines.

Without knowing it, perhaps, Tom has accomplished his day because of years of research in materials science and engineering. Of course, materials scientists and engineers may not have designed and manufactured his car, the jet he boarded or the gas turbine that generated power to cool his home. But those products would not be feasible — and indeed many of them will be realities by 2015 — without solid contributions from the "material world."

"Materials science and engineering is an enabling discipline at the interface of science and engineering," says Dr. Ashok Saxena, chair of the Georgia Institute of Technology School of Materials Science and Engineering. "It is very critical to the performance of a lot of engineering systems."

"A lot" may be an understatement. Materials are everywhere, from your clothes to your house to your car to your workplace to your community. Do you like your computer, your cell phone and your stereo? Well, they wouldn't work without the semiconducting material properties of silicon. Could you do without your refrigerator or stove? Well, you would have to, without fabrication of plastic and metal parts. Do you need to fly across the country today? Well, you couldn't, were it not for materials scientists' discovery of nickel-based super alloys that led to development of jet engines.

Materials are so important, in fact, that entire eras — for example, the Bronze Age and the Iron Age — are named for them. Materials continue to drive technology advancement, though a necessary shift in research is occurring.

"It used to be that materials were found in nature — for example, wood, copper or aluminum," Saxena says. "We used to process these materials and measure their properties. Then we would try to find applications. The emphasis today is to first think of an application and then try to design the right material for that application. That right material may not be a pure metal or a pure ceramic. It might be a composite material that would have constituents of metals or ceramics in it.

"Part of the reason for this shift is that the use of these traditional materials has been optimized. In order to make the next leap forward in terms of performance, materials have been identified as a critical technology. Because these materials don't exist in nature, we have to design the materials for these new applications," Saxena explains.

photo by Gary Meek

Research teams led by Drs. Sue Ann Bidstrup Allen, Cliff Henderson, left, and Paul Kohl are devising a processing technology that could make profound improvements in the fabrication of microfluidic, microelectronic and micro-electro-mechanical devices. (300-dpi JPEG version - 277k)

Thus, the more than 100 Georgia Tech researchers who are working on materials science and engineering projects are developing both novel applications and the materials necessary to make them realities. There is ongoing work — much of it interdisciplinary — with microelectronic materials, structural materials, biomaterials, materials physics and chemistry, and materials processing, for example. It involves researchers from many schools in the College of Engineering and the School of Chemistry and Biochemistry and the School of Physics in the College of Sciences. Researchers interact regularly through collaborative projects and meetings of the Georgia Tech Materials Council.

"Materials science is one of the truly interdisciplinary fields, just by the very nature of it," says Dr. Jean-Lou Chameau, dean of the College of Engineering. "For example, in developing biomaterials, you often need a biology background, a chemistry background and an engineering background."

Georgia Tech materials researchers are working together to understand the fundamental structure of materials and then create new and improved materials with specific properties. Also, they are developing: new ways to characterize materials; mathematical models for predicting material behavior; and new processes for synthesizing and joining materials and methods for fabricating parts of engineering structures.

Some specific areas of research include electronic packaging, nanotechnology and molecular design, environmentally benign materials and processes, optoelectronics, high-temperature materials, composites and photovoltaics. (See the accompanying story links at the top of this page for various project descriptions.)

Saxena believes electronics packaging materials research — specifically, studies on encapsulate materials and the assembly of components — is an especially important area of investigation at Georgia Tech. "For example, if you make an electronics package very small, you dissipate a lot of power," Saxena explains. "That power gets dissipated in the form of heat. You have to find ways to get the heat out. The thermal conductivity of the material then becomes extremely important. Then there are a lot of signals going back and forth, and the dielectric properties of these materials become very important. And the speed of the signal is also important, and it has to do with material properties, as well."

Georgia Tech's Packaging Research Center, under the leadership of Drs. Rao Tummala and C.P. Wong, is developing new materials and process technologies that will lead to smaller electronic packages with several-fold improvements in performance at a fraction of today's cost. The National Science Foundation is funding the center's research.

In the nanoscale realm, Georgia Tech research on carbon nanotubes is yielding applications in microelectronics and other fields in which extremely small conductors and other structures would allow production of new types of nanoscale devices. For example, Drs. Walt de Heer and Z.L. Wang's discovery of new electronic and micromechanical properties of nanotubes led them to suggest a "nanobalance" small enough to weigh viruses and other sub-micron-scale particles.

photo by Joann Vitelli

Georgia Tech civil engineering Professor Dr. Abdul-Hamid Zureick, left, explains to a student the use of fiber-reinforced polymeric material to strengthen bridges. Zureick's studies show this material can make bridges 30 to 40 percent stronger than their original design. He is gathering long-term data to estimate the benefits of the material over a bridge's lifespan.

Chameau cites environmentally benign materials as another hot area of study at Georgia Tech. "We are trying to make products and processes that use less energy, fewer materials and last longer," he says. "To do that requires materials with higher performance, like 'smart' materials. There will be lots of activities in this area in the next few years at Georgia Tech."

Other areas where Georgia Tech is making significant contributions include: carbon fiber-reinforced polymeric materials for bridge reinforcement and repair; a biomaterial called Salubria for replacement of arteries and cartilage in thumb and knee joints; and microcoatings that protect surfaces from heat, which are needed in industries ranging from aerospace to cookware.

Numerous Georgia Tech patents, technology licenses and high-tech, start-up companies are evidence of the significance of materials research at Georgia Tech. One example is a pair of patents for testing elastically tailored composite structures that both extend and twist in response to force. These structures could improve the performance of helicopters, sports cars and sporting goods.

Materials scientists and engineers at Georgia Tech, and elsewhere, are driven to create and refine technologies that can improve our lives in this century and beyond, Saxena says. Though military and NASA applications initially drive much of the research, the technologies are being transferred to numerous industries that affect consumers. Among those products are improved automobiles, microelectronics, aircraft, wireless telecommunications systems and flat panel displays.

"Materials science is critical to new technology," Chameau says. "Everything we do needs to be more efficient, to last longer, to be more effective, to be less expensive, to dissipate energy better. All the products we are making need to have higher capabilities. And all of this relates to the material's properties.... Materials will become more and more critical as we have these requirements for better performance."

For more information, you may contact Dr. Ashok Saxena, School of Materials Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-894-2888) (E-mail: ashok.saxena@mse.gatech.edu).

Also see the Georgia Tech Materials Council Web site at www.matecouncil.gatech.edu for links to campus-wide materials programs or the School of Materials Science and Engineering Web site at www.mse.gatech.edu/.

Research Horizons

A Match Made in the Lab

Georgia Tech assumes science and technology co-management role at Oak Ridge National Laboratory.

By Gary Goettling

An excellent fit — that's how the Georgia Institute of Technology's vice provost for research sizes up the match between Georgia Tech and Oak Ridge National Laboratory in Tennessee.

On April 1, Georgia Tech joined five other core universities in managing science and technology research activities at Oak Ridge, a U.S. Department of Energy facility now operated by the University of Tennessee and the Battelle Institute.

file photo

See sidebar story: **Getting Every Last Detail**

The focused-research areas under way or under development at Oak Ridge embrace materials science, nanotechnology, nanoscience, transportation, biotechnology, and environmental science and technology.

"The list actually reads like Georgia Tech's main thrust areas," says Vice Provost Dr. Charles Liotta, who is also dean of graduate students and a Regents' professor of chemistry and biochemistry. "We think the Tech-Oak Ridge combination is a natural."

Tech is managing these Oak Ridge research activities in collaboration with Duke University, North Carolina State University, Florida State University, Virginia Polytechnic Institute and State University, and the University of Virginia.

"Some faculty who already have relationships with Oak Ridge said this (new partnership) will make those relationships even better and more productive," Liotta says. "Everybody is very excited about this."

In designing energy-efficient space conditioning systems, Oak Ridge National Laboratory scientists relied on data from a team of Georgia Tech Research Institute researchers headed by Dr. Charlene Bayer. The team confirmed the positive effects of humidity control and continuous ventilation on the indoor air quality of schools. (300-dpi JPEG version - 202k)

Dr. Zhong Lin Wang, an associate professor of materials science and engineering, is Georgia Tech's liaison for Oak Ridge research related to materials, nanoscience and nanotechnology. Wang is monitoring research activities and identifying project leadership and collaborative opportunities among all of the parties involved at Oak Ridge.

"The core universities serve two roles," Wang says. "One is to collaborate with Oak Ridge in various research initiatives, and the other is to oversee and help direct the research operation there to help make it operate more efficiently and more fully use its facilities for research."

Tech will seat a representative on each science committee of Oak Ridge's thrust areas and also be the beneficiary of new, joint faculty positions in those areas. The association with Oak Ridge will also provide Tech with extra research muscle that could provide an edge in competition for the establishment of new national research centers or programs, Wang adds.

"Our involvement here goes beyond this specific facility," says Dr. Gary Schuster, dean of the College of Sciences. "Oak Ridge National Laboratory is a national resource. It has facilities that are available nowhere else in the world. To become a part of the consortium that is responsible for its management gives us at Georgia Tech an opportunity to participate in decision-making about those facilities. It will work to the advantage of Georgia Tech to know where it is going in advance of when it gets there. The availability of that information will allow scientists and engineers on our campus to plan better and take advantage of the facilities at Oak Ridge."

By 2006, those facilities will include the most powerful Spallation Neutron Source in the world. (See sidebar.) Its accessibility to Tech faculty will bring a tremendous boost to research activities, and also foster relationships with Oak Ridge and the other core universities in new areas.

But no one is waiting on the neutron source. Discussions began last summer about the best ways to work with each other, says Dr. David McDowell, a Regents' professor in Tech's School of Mechanical Engineering. He organized a core-university workshop, titled "Strategic Southeastern Partnerships: Science and Technology for Energy and Materials."

Workshop participants discussed the idea of building a virtual laboratory in advanced materials at Oak Ridge. The lab could facilitate researchers working together without having to be in the same location and even allow for remote control of instrumentation.

Such a facility may also provide the basis for a "virtual southeastern university," McDowell says, where the core universities "could band together and offer graduate-level courses in areas related to atomic-level characterization, imaging and materials science — areas so specialized that no single university could or would offer them."

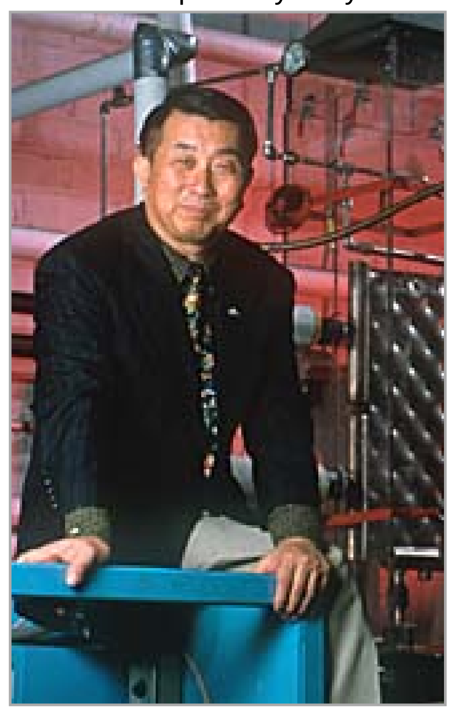
Meanwhile, Georgia Tech is taking advantage of an opportunity to demonstrate leadership in one of its core competencies. Oak Ridge is starting an advanced materials center, and Tech is helping launch the center with a major conference on nanotechnology and nanoscience.

"The conference will involve other universities, industry and government laboratories," Wang explains. "It's a good opportunity to increase our visibility in this very high-interest emerging area of science and technology."

Liotta adds: "Georgia Tech is already strong in nanoscience and nanotechnology. As a consequence, we are ideally poised to be a leader in both regional and national initiatives."

Georgia Tech's latest affiliation with Oak Ridge is built upon a relationship that dates back to the lab's founding during World War II, when Tech alumni were recruited to work on the Manhattan Project. Ever since, the Tech campus has served as a valuable source for recruiting the engineers and scientists who conduct an increasing scope of research and development at the Tennessee complex.

photo by Gary Meek



In collaboration with Oak Ridge National Laboratory scientists, chemical engineer Dr. Jeffrey Hsieh began development of an energy-efficient, cost-effective black liquor concentration process for the pulping industry. (300-dpi JPEG version - 364k)

Descriptions of some Georgia Tech/Oak Ridge projects help illustrate the mutual benefits of the collaboration.

Improving Pulp and Paper Processing

In 1995, the Thermal and Environmental Control Group of Oak Ridge's Efficiency and Renewables Research Section began providing thermal science support to the pulp and paper industry.

With private industry collaboration, Dr. Jeffrey Hsieh of the School of Chemical Engineering worked with Oak Ridge staff to investigate thermal characteristics of the evaporative concentration of black liquors, a critical technology in the pulping process.

The work provided an initial step in development of an energy-efficient, cost-effective black liquor concentration process. Additional activities included the construction of bench-top and pilot-plant falling-film evaporators, and paper mill interactions on commercial-size evaporators.

Engineering Bacteria That Keep Uranium in Place

Keeping waste uranium in its place is the goal of a project under way at Oak Ridge National Laboratory with assistance from Georgia Tech. Oxidized uranium is soluble, which means it may be carried away from disposal sites by rain or streams. To prevent that possibility, researchers are developing a process that renders the waste insoluble. The process causes waste uranium to drop from the water into sediment, where it remains.

The ingenious approach is to combine uranium waste with phosphorous (phosphate), which produces an insoluble mineral. But phosphorous doesn't disperse well enough on its own to reach all of the uranium, so researchers add organic phosphorus material to it. However, while the improved organic phosphorous form disperses throughout an area as desired, it won't readily combine with uranium.

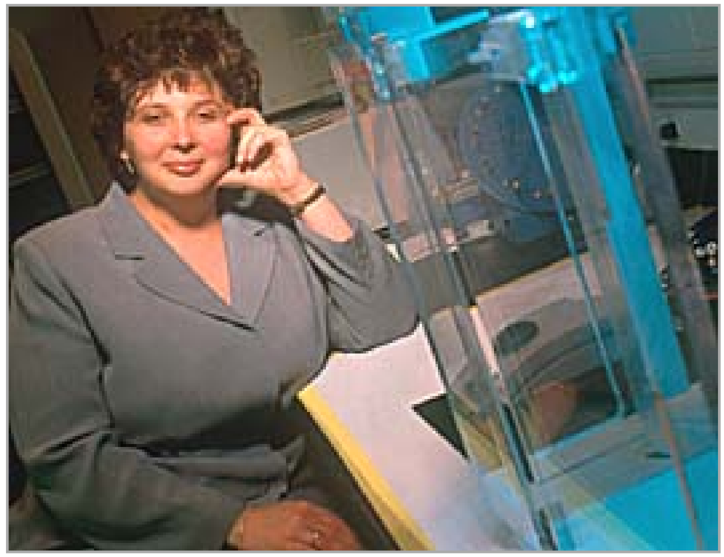
To fix that problem, Dr. Patricia Sobecky, an assistant professor in the School of Biology, is genetically engineering bacteria that, after the organic phosphorous has been spread, can be added to the mix. The bacteria separate the organic material from the phosphorous, thereby aiding the combination of uranium and phosphorous into an insoluble mineral.

The technique, which faces carefully controlled field testing, may also be effective in removing other metals from groundwater.

Helping Buildings Breathe Easier

Making buildings more airtight and energy efficient is often achieved at the expense of sufficient supply ventilation and a lack of humidity control. These factors can result in moisture buildup and poor indoor air quality known as "sick building syndrome."

photo by Gary Meek



Bacteria genetically engineered by biologist Dr. Patricia Sobecky are added to organic phosphorous that is spread over uranium waste to make it insoluble. The bacteria separate the organic material from the phosphorous, thereby aiding the combination of uranium and phosphorous into an insoluble mineral. The process could prevent uranium waste from being carried away from disposal sites by rain or streams. (300-dpi JPEG version - 373k)

When Oak Ridge scientists were looking for new ways to design energy-efficient space conditioning systems that provide high levels of humidity control, they relied in part on data gathered by Georgia Tech.

A team of Georgia Tech Research Institute (GTRI) researchers headed by Dr. Charlene Bayer helped conduct a field study to verify the positive effects of humidity control and continuous ventilation on the indoor air quality of schools and the health of schoolchildren. To develop baseline data for schools in moderate and hot, humid climates, the researchers studied four schools in the metropolitan Atlanta area and six in Georgia's coastal region.

Five schools in the study had active humidity control and continuous ventilation systems, and five did not. The schools were statistically matched as closely as possible. The study has been used to develop recommendations and HVAC design considerations for improving indoor air quality in schools and other large buildings.

The GTRI scientists also involved schoolchildren in the project. Continuous monitors were placed in the schools for more than one year. Children took readings from the monitors and e-mailed the data to GTRI, which maintained a Web site where the children could view the data as it was analyzed, allowing them to view "science in action" and understand more about data gathering and interpretation.

Putting Technology on the Road

The 1996 Summer Olympics created an opportunity to design and test a high-tech traffic management system. Under the auspices of the Federal Highway Administration, the Atlanta Driver Advisory System was developed by a consortium that included Georgia Tech, GTRI and the Oak Ridge National Laboratory. Bill Youngblood, a senior research engineer in GTRI's Aerospace, Transportation and Advanced Systems Laboratory, served as project manager.

Two hundred cars and trucks were outfitted for the test with on-board navigation systems displaying real-time traffic and routing information transmitted by a traffic information control center. Signals from road sensors and satellites — part of the Intelligent Transportation System Infrastructure developed to support the project — helped the control center pinpoint each driver's location with respect to known traffic bottlenecks so alternate routes could be suggested via the on-board display.

Uncovering the Nature of Matter

Georgia Tech School of Physics faculty and students enjoy access to specialized equipment at Oak Ridge, such as that found at the Holifield Radioactive Ion Beam Facility. There, two of Dr. John Wood's graduate students, Brian MacDonald and W. David Kulp, conduct experiments involving a 25-million-volt accelerator and recoil mass spectrometer. The equipment allows the scientists to produce excited nuclei and study their decay to learn more about nuclear structure.

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Research Horizons

Picking Up Good Vibrations

Engineers merge two technologies to improve inspection of power pole crossarms.

By T.J. Becker

Holding up power lines around the world are millions of wooden crossarms. Susceptible to rot, these structures must be inspected periodically — otherwise lines could collapse and cause outages.

No easy task. Traditionally, workers conduct inspections by climbing poles and hitting the crossarm with a hammer; they attempt to judge the condition of the wood by listening to the resulting ring. But these manual inspections are imprecise, time-consuming, costly and hazardous.

photo courtesy NEETRAC

Researchers recently conducted a field test of their new power line crossarm inspection system that combines laser vibrometry and neural networks and allows workers to analyzes crossarm structural integrity from the air. The process drastically reduces costs, while also boosting accuracy. (300-dpi JPEG version - 489k)

Georgia Tech researchers have merged two technologies — laser vibrometry and neural networks — to create a remote inspection system that analyzes crossarms from the air, drastically reducing costs while boosting accuracy.

Work began two years ago when principal researcher Paul Springer of the School of Electrical and Computer Engineering responded to a request from Entergy Services Corp., which funded the project. A global energy provider headquartered in New Orleans, Entergy maintains more than 100,000 crossarms.

Program manager of mechanical systems at Georgia Tech's National Electric Energy Testing, Research and Application Center (NEETRAC), Springer specializes in dynamics — how objects respond when struck or shaken. Drawing upon dynamics as well as his musical background, Springer began to think about crossarms as a sounding board: "If there's good structural integrity, it's going to have a more pleasing tone when struck."

Springer reasoned that a laser Doppler vibrometer mounted on a helicopter could measure crossarm response to the helicopter's engine and rotors, thus eliminating the need to make direct contact with the structure. "It's similar to using a laser gun to detect the speed of a car," Springer says. "Except instead of measuring speed, the vibrometer detects the vibration of a surface by bouncing a laser beam off it." Damaged wood should give a different vibration spectrum than healthy wood.

There was just one hitch: The laser vibrometer could get measurements, but it wouldn't interpret the results of those measurements. So Springer turned to Dr. James Mahaffey in the Georgia Tech Research Institute's Information Technology and Telecommunications Laboratory.

"This is a classic application of neural network technology," Mahaffey says. "There are no set rules about whether the vibrations indicate a good crossarm or a bad one. You need an advanced signal processing method."

Neural networks are a type of computer artificial intelligence that attempts to imitate the way a human brain works. By harnessing the power of computers to sort massive amounts of data for patterns, neural networks create an algorithm of sorts. After "learning" from training data, they eventually can predict a reliable outcome from data never seen before.

Springer and Mahaffey began initial testing with 15 crossarms provided by Entergy. In a lab setting, an accelerometer measured crossarm vibrations while a gasoline engine operated nearby to simulate helicopter noise. After researchers recorded vibration spectra, they broke the crossarms to determine their condition — a healthy crossarm requires much more force to break than one that's rotting.

Researchers then used data from seven of the 15 crossarms to train the neural network. They divided the vibration frequency spectrum from each crossarm into 200 pieces (ranging from 25 Hz to 520Hz) and then fed the information into the neural network. Researchers used the remaining crossarms to determine whether the neural network had learned to recognize crossarm condition based on vibration spectra. "We already knew what breaking strength was, so we compared actual value against the estimated value," says Dr. Ronald Harley, a professor in Georgia Tech's School of Electrical and Computing Engineering. He joined the project last summer.

Lab tests indicated a strong correlation between vibration signals and crossarm strength. The next step was to procure a laser vibrometer and test its ability to make remote measurements.

Air2, a Miami-based flight company, provided a helicopter that enabled NEETRAC research engineer Janeen McReynolds to conduct a field test in January.

Researchers had two goals for the field test: (1) Determine whether the laser vibrometer would work from the air and (2) obtain a larger sampling of crossarms to fine-tune the neural network. "The wider the sample of crossarms, the more accurately you can train the neural network," Harley explains. "It can only learn from those things you show it."

With data collected from 92 crossarms, the field test "far exceeded the most optimistic expectations," Springer says.

Springer, Mahaffey and the Georgia Tech Research Corporation have already filed a provisional patent application, and now the technology is almost ready for commercialization. There are still a few considerations to address, Springer says: "There are no commercially available vibrometers with enough power to get a vibration signal from a long distance. Fortunately, a long-range vibrometer will soon be available." Less expensive vibrometers require helicopters to fly in at closer range, he explains, which makes inspecting more time-consuming and cuts into the economic feasibility.

Yet even by conservative estimates, savings are impressive. Average costs for manual inspections are $50 per crossarm. Using a laser vibrometer and neural network, remote inspections would slice that to about $5 per structure — one-tenth of current costs.

"Utilities are responding to deregulation by searching for ways to reduce costs and improve the reliability of electric transmission systems," Springer says. "This project will lower inspection costs and improve accuracy. Utilities will be able to use wood components longer because strength, rather than appearance, is the inspection criterion. Components with hidden flaws are detected, while structurally sound parts with superficial defects can remain in service."

For more information, contact
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Last updated: May 22, 2000

Research Horizons

Fueling the Fire

Investments in university research help ignite $136 million Digital Furnace deal — and new Yamacraw broadband design jobs.

By T.J. Becker

Two announcements earlier this year provide strong validation for Georgia's strategy of investing in university research to spur development of technology-based start-up companies and new jobs from existing firms.

photo by Sue Clites

The first announcement involved Digital Furnace Corp., which barely a year ago bowed before investors at the Venture Market South venture capital conference in Atlanta. The company, which provides broadband voice, data and video solutions, was the talk of this year's conference when it revealed Feb. 28 that it would be acquired by Broadcom Corp. of Irvine, Calif., in a stock trade then valued at more than $136 million.

Digital Furnace's flagship software, Propane (tm), uses sophisticated algorithms to improve efficiency of broadband networks, as much as tripling the speed of data flow. The acquisition will enable Broadcom, a leading provider of integrated circuits, to turbocharge its cable modem chips.

The second announcement came March 9, when Georgia Governor Roy Barnes unveiled Broadcom's plan to create 100 broadband communications development jobs in Georgia over the next five years as a member of the Yamacraw Design Center. The move will help the company maintain leadership of broadband communications technology.

Digital Furnace engineer Beth Wilcher checks data from the company's Propane™ software, which can triple the speed of data flow over broadband networks. (300-dpi JPEG version - 310k)

Some Synergistic Matchmaking

Digital Furnace's success story unfolded so rapidly that it amazed even its founders — John Lappington, Dr. John Limb and Daniel Howard — who credit Georgia Tech and the Georgia Research Alliance (GRA) for providing resources and a setting that enabled them to commercialize basic research at lightning speed.

In fall 1998, Lappington had some time to spare, having left an executive post at Antec Corp. under a non-compete agreement. He volunteered to do some work for the Advanced Technology Development Center (ATDC), Georgia Tech's incubator for high-tech start-ups. ATDC's Ben Hill introduced him to Limb and Howard in the Georgia Center for Advanced Telecommunications Technology (GCATT), a research facility supported by the GRA at Georgia Tech.

Recruited to Georgia Tech in 1994 as a GRA Eminent Scholar, Limb launched GCATT's Broadband Telecommunications Center (BTC) along with Howard, and the two were researching ways to improve speed and efficiency of cable modems. The trio began pooling ideas — in particular, looking at ways to improve the DOCSIS industry standard — and decided to form a company.

Digital Furnace was soon up and running and entered the ATDC fold. Lappington admits he was initially lukewarm about joining ATDC: "I didn't feel I needed it." No rookie entrepreneur, Lappington co-founded Electronic Systems & Products in 1989 and Digital Video in 1993.

Yet Lappington changed his mind about ATDC's value as Digital Furnace moved forward. Compared to his previous start-ups, Digital Furnace has been "a piece of cake," Lappington says. "Now I'm a disciple."

ATDC allowed Digital Furnace to focus its efforts on product development instead of infrastructure, Lappington explains. By providing office space, phone and computer systems, along with access to a network of attorneys and other service providers, the incubator eliminates a myriad of details that can distract entrepreneurs.

Upstairs, Downstairs

ATDC leased Digital Furnace space on the fourth floor of GCATT, which had been built by the GRA to help bring industry and university faculty together under one roof.

Indeed, proximity to researchers proved crucial to Digital Furnace's blast-off, Howard says: "When you're in GCATT, you're one or two floors away from the people you're giving research grants to." Typically, industry and researchers are isolated, and weeks can pass without contact — the lack of communication taking a toll on commercialization. No such gap exists at GCATT where a constant rubbing of shoulders keeps everyone on track.

The GCATT location was also an asset for Limb. A professor in Georgia Tech's College of Computing, Limb continued teaching. Yet with his second-floor office just two floors away from Digital Furnace, Limb was able to optimize time with both students and the start-up. Other universities allow faculty to consult with industry, but Georgia Tech bends over backward to help, Limb maintains.

Access to an immediate talent pool was another plus; Digital Furnace hired several grad students to help with R&D. "This is a fast-changing technology," Limb says. "Students here are on the leading edge of technology. When given a problem, they can understand it and attack it quickly."

Aside from logistics, ATDC helps entrepreneurs fine-tune their market strategies. "We learned that there was a very narrow window of opportunity for companies like us," Howard says. If you're solving a problem that everyone knows about, large companies are undoubtedly working on it, too. On the other hand, start-ups must take care not to work too far ahead of the curve — otherwise they'll run out of funding.

photo by Sue Clites

Georgia Tech Professor Dr. John Limb, left, and former Tech researcher Daniel Howard, center, teamed up with entrepreneur John Lappington to form Digital Furnace Corp. The company's flagship product uses sophisticated algorithms to improve efficiency of broadband networks, as much as tripling the speed of data flow. (300-dpi JPEG version - 480k)

A Higher Survival Rate

Indeed, Digital Furnace's exponential growth reflects a new trend in collaboration as independent university programs partner together in the spirit of economic development.

When ATDC opened its incubator in GCATT in 1996, it was an innovative experiment in technology transfer. "Too often research operates in a vacuum — even if it's sponsored by industry. By putting incubator space in a research facility, we're fostering interaction between researchers, business and investors," says Wayne Hodges, director of Georgia Tech's Economic Development Institute and ATDC.

In just 18 months, Digital Furnace accelerated from a three-person company to more than 35 employees — high-tech jobs that will remain in Georgia as the company is folded into Broadcom's residential services unit in Atlanta.

"This is the one of the biggest successes that we've seen — and not just from the financial side. This is the first time all the pieces of the puzzle have been put into play," says C. Michael Cassidy, the GRA's president, pointing to the networking among his organization and ATDC. Even Alliance Technology Ventures, which provided Digital Furnace with $500,000 in seed money, traces its roots to GRA.

Digital Furnace's new owner is no stranger. A few years ago, the California-based Broadcom sent a landing party to Atlanta, taking root first at the ATDC. The move stemmed from Limb's efforts to establish an industry "test bed" within BTC. Deeming Limb a magnet, Cassidy says. "If you get the right people here, industry flocks."

Broadcom Joins Yamacraw

More "pieces of the puzzle" came together when Governor Roy Barnes announced that Broadcom had become a member of the Yamacraw Design Center. The state-funded initiative aims to bring high technology jobs to Georgia and enhance the state's leadership in the field of electronic design for broadband communication technology. The Yamacraw Design Center serves as the focal point for the initiative's multi-agency economic development effort.

"Broadcom's technology and focus make the company a perfect fit for the Yamacraw Design Center," Barnes says. "These are precisely the type of jobs we expected Yamacraw to attract to Georgia."

Thomas J. Quigley, senior director of Advanced Broadband Architectures for Broadcom, says the company shares Yamacraw's view that advanced broadband communications technologies are critically important to enabling a future Internet economy.

"In order to tap into the full potential that an Internet-fueled economy promises, massive amounts of information in the form of voice, video and data must be quickly and easily transferred between homes and businesses around the world," noted Quigley. "Broadcom is committed to maintaining a leadership position in the design of high-speed data transmission devices over a broad spectrum of communications networks. Our partnership with Yamacraw will help us combine our strength in design and commercialization with ongoing research into these technologies."

Broadcom will work closely with the Yamacraw research faculty to identify market needs in the area of high-speed data transmission that can be addressed through research at the Yamacraw Design Center. Both Broadcom's Atlanta operations and Digital Furnace were spearheaded by Georgia Tech graduates, benefitted from business advice and office space provided by the ATDC, interacted frequently with researchers from the Broadband Telecommunications Center at GCATT, and together already employ 100 high-tech Georgia professionals.

"Our work with the Broadband Telecommunications Center has shown us the quality of research in Georgia. Working with the Yamacraw Design Center will give us expanded access to the work of top researchers and give Broadcom entrée to their students upon graduation," Quigley says. "Broadcom hopes to double its staff in Georgia over the next five years. Working closely with the students in the Yamacraw Mission will make it much easier for us to find qualified people for those positions."

Dr. James Foley, Yamacraw executive director, says Broadcom's decision to join the Yamacraw Design Center confirms that Yamacraw's research is providing a firm basis for commercial development. Says Foley: "Broadcom's established success in turning design research into commercial applications makes Yamacraw's pool of talent a great resource for the company."

The twin announcements show the benefits that can arise from partnerships between Georgia's research community and state's growing band of experienced entrepreneurs.

There are more John Limbs out there doing research "ripe for guys like me to build companies from," Lappington agreed. "Unfortunately, I'm going to be busy for awhile."

For more information, contact Lucy Henner, Broadcom Corp., 4920 Avalon Ridge Parkway, Suite 600, Norcross, GA 30071-1572. (Telephone: 770-263-0911) (E-mail: lhenner@broadcom.com).

Research Horizons

Research Notes

Carving a Niche in Broadband Wireless

Company founded by Georgia Tech researchers is developing semiconductor chips for a booming broadband market.

A high-tech company founded by Georgia Institute of Technology faculty and staff members is developing semiconductor chips to fuel the upcoming boom in broadband wireless communication.

RF Solutions, which is a 2-year-old member company of Georgia Tech's Advanced Technology Development Center (ATDC), has been transitioning from its roots as a consulting firm specializing in analog circuit design to a product-oriented company.

photo by Gary Meek

RF Solutions, an ATDC company, is developing semiconductor chips to fuel the upcoming boom in broadband wireless communication. Here, two company engineers show a printed circuit board. (300-dpi JPEG version - 210k)

"We produce the circuits and chips that are the engines of every wireless device," says CEO Steve Richeson. "Our products will be analog and radio frequency semiconductors used in broadband wireless products. These will be in very high demand for future consumer products."

The first RF Solutions chips will be part of a transceiver system allowing cable modems to work in a fixed wireless environment for providing connection to the Internet. But there are many other potential applications for the technology.

"The market is vast because the chips we are making will be in devices that we haven't even thought of yet," Richeson says. "Every wireless device will need to have a transceiver."

The company hopes to grow in a niche semiconductor market dramatically different from the traditional digital silicon. To provide the interface for sending high-bandwidth signals up to 30 miles through the air, the company's chips will be analog and operate at radio frequencies. To meet those performance standards, the circuits will be built on compound semiconductors such as gallium arsenide, a material very different from the silicon that is the foundation for ordinary computer chips.

Though outside the norm for most Silicon Valley companies, analog device design, radio frequency transmission and compound semiconductor fabrication are research strengths at Georgia Tech. The company considers access to this expertise — and skilled graduates — a key competitive factor.

"This is a different technology and a different set of design skills, and in the wireless industry today, there are simply not enough analog design engineers," Richeson explains. "We have access to essentially an unlimited supply of analog engineering talent from Georgia Tech because of our connections and location."

The company also expects to gain an advantage through use of a proprietary design process called X-Cellacore(tm). This process should reduce the time required to put new analog semiconductor chips into production by as much as 60 percent.

"Wireless broadband modems will become consumer electronic devices," Richeson says. "Time to market in that competitive area will be critical. The people who will use our chips will have to differentiate themselves and come up with new products every six months or so."

The company will contract with existing semiconductor fabrication facilities to manufacture its chips. But if that market really takes off, Richeson says Georgia could potentially justify the huge capital investment required to construct a fabrication plant.

— ***John Toon***

> **The full-text version** of this article is posted at www.atdc.org/companies/february232000.html. **For more information,** contact Catherine Cass, RF Solutions, 430 10th St. NW, Atlanta, GA, 30318. (Telephone: 404-876-7707, Ext. 12) (E-mail: ccass@rfsolutions.com)

Keeping It Clean

Microelectronics work focuses on improved cleaning of integrated circuits.

A promising technique for improved cleaning of integrated circuits could replace a method that by design creates an incompatibility, which slows the manufacturing process.

Integrated circuits (ICs), miniature assemblies of electronic components vital to the electronics industry, must be ultra clean to function properly. Most traditional cleaning processes use liquids, typically acids and bases. But these processes must interface with vacuum chambers, where most IC fabrication steps occur. After liquid cleaning of IC substrates, manufacturers must insert a drying step before starting vacuum processes.

photo by Sue Clites

A new integrated circuit cleaning technique developed by chemical engineering Professor Dennis Hess, right, streamlines the IC fabrication process and makes it more environment friendly. Graduate student Tazrien Kamal shows Hess a treated sample in his laboratory. (300-dpi JPEG version - 246k)

Now, a Georgia Institute of Technology professor has devised a new IC cleaning technique that eliminates that drying step, streamlining the fabrication process and making it more environmentally friendly.

"This new process takes advantage of what we know about liquid cleaning, but modifies the approach to be compatible with vacuum processes," says Dr. Dennis Hess, a professor in the School of Chemical Engineering and an investigator at the Microelectronics Research Center.

In research funded by the National Science Foundation and Los Alamos National Laboratory, Hess is experimenting with a liquid-phase cleaning that can be combined with vacuum processes. He heats water to temperatures above the boiling point while simultaneously adding pressure to keep the water in the liquid phase. After the cleaning is complete, Hess reduces the pressure and flashes the liquid off the surface.

This new technique is also "greener" than other approaches, Hess says, because it uses water instead of the toxic and corrosive chemicals traditionally used for IC cleaning. The technique shows promise, he adds, but he does not yet know if it is feasible for the production process.

"At this point in our work, we need to collaborate with IC equipment manufacturers or IC device manufacturers to try out the method on actual IC wafers so we can assess the stability of the approach for large-scale fabrication," Hess says.

He is discussing the technique with several companies to determine their interest in testing it in the very complex manufacturing process for ICs.

The fabrication of ICs starts with wafers made from ultra-pure silicon, which are polished to a mirror-like finish. Then layers of thin films are deposited onto the wafer. Next, patterns are etched into the film surfaces to define features of individual circuit elements that will compose the circuits. These steps are repeated again and again with different film layers until the IC unit is complete.

This complex fabrication process takes place in a clean room, a specialized manufacturing environment. But even in this ultra-clean environment, cleaning the circuits between processing steps is critical. Of the 400 process steps necessary to make a typical integrated circuit, about 50 to 60 of these involve cleaning the film and substrate surfaces.

"Impurities are naturally introduced through the (manufacturing) process," Hess says. "Cleaning the surfaces is often done as a precautionary measure." But it is a step that is taken very seriously.

A lot of research has been done on cleaning wafers using vapors, but this technique has not been successful so far because of the extreme complexity. Also, the cleanliness level may not be equivalent to that of traditional techniques, Hess says.

Hess' research presents numerous challenges. For example, he has discovered that in spite of the many advantages of using water to clean surfaces, there is a downside: The reactivity of the water is very high and can actually etch the silicon wafer. Therefore, Hess is looking at other options, including the possibility of using additives to mediate the reactivity.

— ***Patricia J. West***

> **For more information,** you may contact Dr. Dennis Hess, School of Chemical Engineering, Georgia Tech, Atlanta, GA 30332-0100. (Telephone: 404-894-5922) (E-mail: dennis.hess@che.gatech.edu)

GTRI Journal of Technology

The online *GTRI Journal of Technology* provides an in-depth look at technology being developed at the Georgia Tech Research Institute, Georgia Tech's applied research organization. Now in its third volume, the full-text *Journal of Technology* is available on the Web at www.gtri.gatech.edu/jot/.

The current issue includes technical papers on: testing implantable medical devices against electromagnetic environments; modeling emitters in an air defense environment; and a new system for improving defense supply systems. The titles and authors are:

- *E3 Testing of Implantable Medical Devices — Past and Present.* Ralph M. Herkert, Jimmy A. Woody and Hugh W. Denny.
- *Using OPNET for Modeling of Non-Communications Emitters in an Air Defense Environment.* J.R. Marks and K.L. Selvidge.
- *Wildcat Tracking System: Cost Savings Through Supply Redistribution.* James P. Coleman, Jr. and David P. Millard.

Also see *Research Links* news stories.

Research Horizons

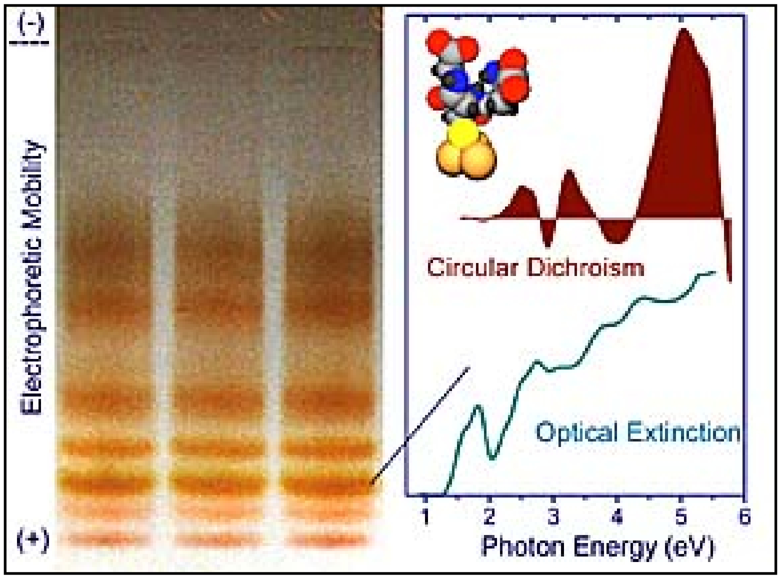
Research Links...

On the Other Hand

Researchers find first experimental evidence of optical chirality in tiny nanoclusters of gold.

Tiny nanoclusters of metallic gold — assemblies containing between 20 and 40 gold atoms encapsulated by a common biomolecule — can display distinctly chiral properties.

courtesy Dr. Robert Whetten



Experimental results show that tiny clusters of gold can show distinctly chiral optical properties. This figure shows electrophoretic separation of gold: glutathione cluster compounds, left, the circular dichroism effect observed, upper right, and optical extinction, lower right, of the third separated band. (300-dpi JPEG version - 529k)

The chiral nature of the clusters, which means they exist in distinct right-handed and left-handed variations, dramatically affects the way in which they absorb polarized light. This optical effect had been predicted theoretically to occur in metal nanostructures, but Georgia Institute of Technology researchers were the first to measure it in a special class of clusters they formulated. Their research was published in the March 30 issue of the *Journal of Physical Chemistry*.

"When clusters are prepared in this way, we see that the conduction electrons in the gold circulate in such a way as to have the unique optical effect of preferring one direction of circularly polarized light over the other direction," explains Dr. Robert L. Whetten, a professor in the School of Physics and School of Chemistry and Biochemistry. "The effect was enormous, which was unexpected."

The gold nanoclusters are believed to be the smallest ever prepared. Dr. T. Gregory Schaaff, a former graduate student in Whetten's lab and now a staff scientist at Oak Ridge

National Laboratory, attached glutathione — a common sulfur-containing tripeptide — to individual gold atoms to form a gold-glutathione polymer in which the gold atoms make no direct contact with one another. The decomposition of this polymer yields the gold clusters, which have glutathione molecules adsorbed to their surface so as to physically limit the number of metal atoms that could join together in each cluster.

While measuring the properties of the clusters, Schaaff noted dramatic differences in the way the smallest clusters absorbed polarized light in the visible and near-infrared spectra. In one cluster, this circular dichroism effect exceeded 300 parts per million (ppm) in the yellow-green region, while in another, the effect exceeded 1,000 ppm in the red and near-infrared.

These optical measurements suggest that the clusters have a helical structure that Whetten compared to the stripes on a candy cane or a barbershop pole.

"We had to double-check our instruments and repeat the measurements a number of times because the effect was enormous," he says.

Using gel electrophoresis to separate the clusters by weight, Schaaff found that certain cluster sizes dominated, with 28-atom assemblies — slightly less than one nanometer across — being the most common. The chiral properties varied by the size of the cluster, and therefore were only observed clearly when the clusters were separated by weight.

Only clusters with 40 or fewer atoms displayed the intense optical properties. The optical effect changed direction as the researchers moved from one cluster size to the next, suggesting a direct correlation to the energies of the conduction electrons in the metal's outer shell.

"Even though the optical absorption increases more or less monotonically here, the preferences for right- versus left-handed light changes direction from one band to another," Whetten notes. "The optical spectra are not smeared out. They each have their own distinct character, plus or minus, corresponding to the energy level."

He believes the effect is related to the high level of confinement created in the conduction electrons by formation of the small clusters, though research has not yet confirmed that. A helical geometrical pattern or "tiling" of the glutathione adsorption sites (gold-sulfur bonds) could also affect the circulation of the conduction electrons.

The implications and potential uses for the effect also remain to be determined.

— John Toon

The full-text version of this article is posted at www.gtri.gatech.edu/res-news/CHIRALGOLD.html. **For more information,** you may contact Dr. Robert Whetten, School of Chemistry and Biochemistry, Georgia Tech, Atlanta, GA 30332-0400. (Telephone: 404-894-8255) (E-mail: robert.whetten@physics.gatech.edu)

Feeding the World by Cleaning the Air

Study ties heavy regional haze to reductions in China's crop production.

A recent Georgia Institute of Technology study suggests that cleaning up the air may help feed the world.

The study found that heavy regional haze in China's most important agricultural areas may be cutting food production there by as much as one-third. The study was published in the *Proceedings of the National Academy of Sciences* last fall.

courtesy Dr. William Chameides

Georgia Tech researchers have found that heavy regional haze in China's most important agricultural areas may be cutting food production there by as much as one-third. The estimates of crop production losses are based on detailed long-term measurements at Nanjing, shown here, 200 miles southwest of Shanghai, but are extrapolated to other areas of China. (300-dpi JPEG version - 380k)

Covering one million square kilometers or more, the haze scatters and absorbs solar radiation, reducing the amount of sunlight reaching key rice and winter wheat crops. That decreases plant growth and food production.

"For crops that are irrigated and fertilized, there is often a direct correlation between how much is grown and how much sunlight reaches those crops," says Dr. William L. Chameides, Smithgall Chair and Regents Professor in the School of Earth & Atmospheric Sciences. "In China, there is a significant amount of haze that reduces the sunlight reaching the surface by at least 5 percent, and perhaps as much as 30 percent. The optimal yields of crops in China are likely reduced by the same percentage."

Chameides says the NASA-funded study provides China — and other nations with similar issues — another option in the struggle to feed their growing populations. It is believed to be the first work to quantitatively assess the direct impact of regional haze on the yields of these crops.

"China is already losing 10, 20 or even 30 percent of its crop production to haze," he says. "Controlling the sources of the haze represents a potential way to increase crop production because the technology exists to control air pollution."

The estimates of crop production losses are based on detailed long-term measurements at Nanjing, 200 miles southwest of Shanghai, but are extrapolated to other areas of China. They consider only the direct effects of haze on sunlight, and do not include the indirect effects on sunlight potentially caused by haze interacting with clouds or the toxic effects of air pollutants that also reduce crop growth.

Extensive studies by agricultural researchers have documented the relationship between crop production and the sunlight received.

The haze affecting China is made up of aerosols composed of solid and liquid particles of varying sizes. The aerosols likely result from the burning of coal, biomass and other fuels, though scientists lack detailed information on their origins.

Large-scale regional hazes exist in other developing countries, suggesting food production may be similarly reduced in India and African nations that are also struggling to feed their people.

"Any economically developing or developed country will have these large regional hazes associated with burning," Chameides explains. "Burning fossil fuels, burning wood and burning biomass for clearing fields causes production of a significant amount of haze that leads to a reduction in the solar radiation reaching the earth's surface."

The same effect has been measured on the East Coast of the United States, though China's haze levels are roughly twice as bad. Records suggest that China's haze problem has worsened over the past 20 years, a time of massive industrialization.

The study, for which Chameides is the lead investigator, found that the regional haze affects approximately 70 percent of crops grown in China. The haze tends to be worst in the eastern part of the country that includes the most productive and heavily cultivated areas. It can be measured year around.

The study produced two different estimates of sunlight reduction, one based on direct measurements and one based on a model of China's atmosphere. Data based on direct measurements suggest an even larger effect than the 5 to 30 percent crop reduction calculated by the model.

— John Toon

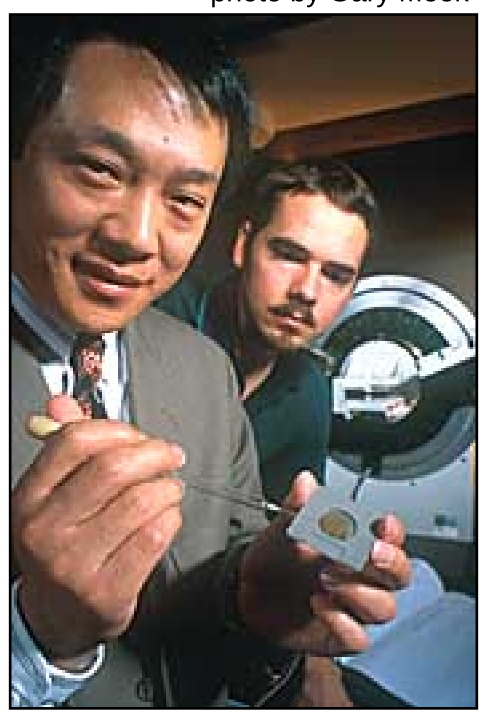
The full-text version of this article is posted at www.gtri.gatech.edu/res-news/CHINA-AIR.html. **For more information,** you may contact Dr. William Chameides, School of Earth and Atmospheric Sciences, Georgia Tech, Atlanta, GA, 30332-0340. (Telephone: 404-894-1749) (E-mail: william.chameides@eas.gatech.edu)

Finding the Right Recipe

Researchers control chemistry to tailor magnetic nanoparticles for medical treatment and diagnosis.

Nanoparticles that possess magnetic properties offer exciting new opportunities for delivering drugs to targeted areas in the body, replacing radioactive tracer materials, improving the quality of noninvasive medical imaging and producing ever-smaller data storage devices. But before these magnetic nanoparticles gain widespread use, scientists must learn to consistently control their key properties.

photo by Gary Meek



Using only variations in chemistry and process conditions, researchers at the Georgia Institute of Technology have learned to precisely control the size and magnetic properties of one class of magnetic nanoparticles. Their goal is a "recipe book" other researchers could use to produce nanoparticles with exactly the right properties for different applications.

"If you are going to produce these nanoparticles for large-scale use, you cannot guess at the conditions or rely on intuition," says Dr. John Zhang, Georgia Tech assistant professor of chemistry and biochemistry. "We are understanding the fundamental ways to control the properties of these particles, chemically manipulating the magnetic interactions at the atomic level. We want to control these properties through chemical means."

Zhang presented his research team's latest findings earlier this spring at the American Chemical Society's 219th national meeting. The team includes Adam J. Rondinone, Anna C.S. Samia, Chao Liu, and Richard Anderson.

Researchers Dr. John Zhang, left, and Adam Rondinone display a sample of magnetic nanoparticles ready for analysis by X-ray diffraction. Such nanoparticles could lead to new methods of delivering drugs to targeted areas in the body. (300-dpi JPEG version - k)

Because each potential application for the magnetic nanoparticles requires different properties, the work is essential to their future use as carriers of drugs, tracers and MRI contrast enhancement agents. Also, it will provide insights to some key technical issues in high-density information storage.

For instance, each particle possesses certain magnetic orientations just as the north or south pole in a tiny magnet. Magnetic digital data bits in a computer hard disk have magnetic states similar to the nanoparticles. When the bits get smaller as the storage density increases, the magnetic state could become unstable. To avoid data loss caused by magnetic state change from simple temperature fluctuations, computer makers need to install a high enough magnetic energy barrier to stabilize the magnetic states.

But for magnetic nanoparticles to be used in the body, physicians need particles with a low-energy barrier to allow magnetic state to change constantly. Because magnetic opposites attract one another, the magnetic particles could potentially clump together, clogging blood flow. Rapidly changing the magnetic direction, therefore, would be essential to prevent the particles from aggregating.

"We know that the energy barriers in these magnetic nanoparticles are due to atomic-level magnetic interactions," Zhang explains. "We want to make the connection between these atomic-level interactions and the macroscopic behavior that we want in these materials."

The energy barrier between magnetic states — which Zhang likens to a hill that requires a certain amount of energy to climb over — is proportional to the size of the particle as well as magnetic interactions. Zhang and his team have learned to control this energy barrier through chemical means. Another critical property is the size. Magnetic nanoparticles for in-vivo biomedical use must be small enough to avoid detection by the immune system, yet large enough to remain in the body long enough to be circulated through the blood stream.

And because magnetic properties vary by size, the particles must all be about the same diameter to ensure consistent properties. Zhang and his team have developed a statistical model to predict and control the size of the nanoparticles from synthesis process variables. They produce nanoparticles with size variations of less than 15 percent, but hope to reduce that further.

— *John Toon*

The full-text version of this article is posted at www.gtri.gatech.edu/res-news/NANOPART2.html. **For more information,** you may contact Dr. John Zhang, School of Chemistry and Biochemistry, Georgia Tech, Atlanta, GA 30332-0400. (Telephone: 404-894-6368) (E-mail: john.zhang@chemistry.gatech.edu)

Faculty Awards and Honors

Dr. Krishan Ahuja of the Georgia Tech Research Institute was named AIAA Engineer of the Year, which is a national award. Ahuja conducts research in the Aerospace, Transportation and Advanced Systems Laboratory. He is also a Regents researcher and professor in the School of Aerospace Engineering.

Dr. Erian Armanios of the School of Aerospace Engineering received a Regents' Teaching Excellence Award for 2000. The awards are designed to honor impressive work being done within the University System of Georgia.

Oxford University Press recently published *Strategic Corporate Management for Engineering* by **Dr. Paul Chinowsky** of the School of Civil and Environmental Engineering. Chinowsky has been studying the management practices of engineering and construction organizations throughout the United States since 1995. This book is based on the largest collection of research data on these organizations in the country.

Dr. Imme Ebert-Uphoff in the School of Mechanical Engineering received a 2000 CAREER Award from the National Science Foundation. Her project is titled "New Research Directions for Parallel Manipulators-Investigation of Redundant Actuation, Redundant Sensing and Static Balancing" and is funded for a four-year period at about $200,000.

Dr. Charles Eckert of the School of Chemical Engineering received a Regents' Research in Undergraduate Education Award for 2000. The awards are designed to honor impressive work being done within the University System of Georgia.

Dr. Augustine O. Esogbue of the School of Industrial and Systems Engineering was elected to the 2000 Class of Fellows of IEEE, the largest engineering professional society in the world. Esogbue was cited for "his contributions to theoretical and computational dynamic programming and applications."

Dr. Rigoberto Hernandez in the School of Chemistry and Biochemistry was named a

2000 Sloan Research Fellow. Awarded by the Alfred P. Sloan Foundation, the two-year fellowship is intended to enhance the careers of the best young faculty members in the nation, especially those who have demonstrated independent creativity in their work. Hernandez's group develops models to better understand the dynamics of thermosetting polymers.

Dr. Michael D. Meyer, professor in and chair of the School of Civil and Environmental Engineering, received the Theodore M. Matson Award for outstanding contributions in the field of transportation engineering. Meyer was recognized not only for his writings and teaching, but also for his leadership in the profession.

The Institute of Electrical and Electronics Engineers honored 21 Georgia Tech faculty members recently with Third Millennium Medals recognizing outstanding contributions in their areas of research expertise. Those recognized were **Drs. Donald E. Clark, David P. Millard, Edward K. Reedy, Mark A. Richards, Bob Trebits** and **James C. Wiltse,** all of GTRI; and **Drs. Tom Barnwell, John A. Buck, Nikil Jayant, Nan Jokerst, John Limb, Jim McClellan, Jim Meindl, Russ Mersereau, Andrew F. Peterson, Teddy Puttgen, Pete Rodrigue, Bill Sayle, Ron Schafer, Rao Tummala** and **Roger P. Webb,** all of the School of Electrical and Computer Engineering.

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